**Calorimeters**

Each of these blocks has roughly the same mass.

They are all heated to 100oC.

The specific heat capacity of each metal is given.

Steel

Specific heat capacity

**420 J/kg/ oC**

Aluminium

Specific heat capacity

**900 J/kg/ oC**

Lead

Specific heat capacity

**160 J/kg/oC**

Brass

Specific heat capacity

**380 J/kg/ oC**

**Safety**

Moving hot metal blocks with tongs needs care and attention.

Do not stir with a thermometer because the bulb is very delicate.

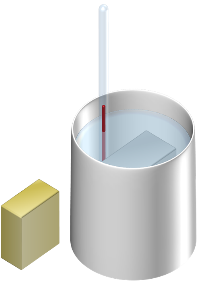
**Apparatus and materials**

* Metal blocks (of equal mass)
* Calorimeter
* Thermometer (0-100oC)
* Stirring rod
* Measuring cylinder (100cm3)
* Tongs
* Beaker (250cm3)
* Bunsen burner, tripod, gauze, mat

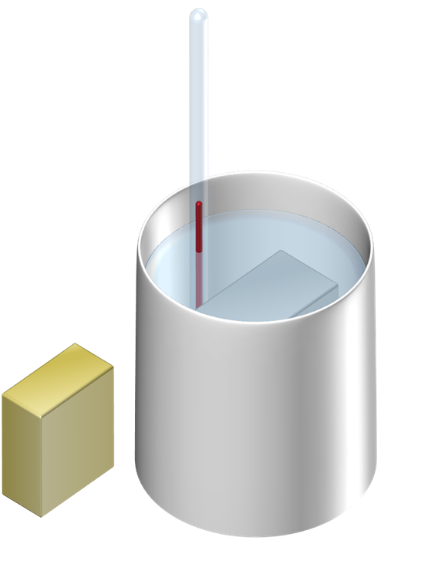
**Procedure**

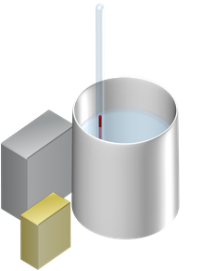
1. Heat the blocks\* in plenty of water in the beaker until the water has been boiling for several minutes.

This allows the blocks to reach the same temperature as the boiling water.

1. Measure out 100cm3 of cold water, add it to the calorimeter and measure its temperature.
2. Use the tongs to place a hot metal block into the calorimeter.
3. Stir the water with a stirring rod and measure the highest temperature it reaches.
4. Calculate the *increase* in temperature of the water.
5. Repeat these measurements for each block in turn.

\*It is quickest if each group takes results for a different type of block and results are shared.

**Calorimeters**

Hot metal blocks are added to cold water and the increase in temperature is measured.

**Predict**

Which block will increase the temperature of cold water the most?

How much more will it increase the temperature than the other blocks?

**Explain**

Why do you think the temperatures will go up like this?

|  |
| --- |
| **Measure the increase in temperature of water for each block.** |

**Observe**

Record the increase in temperature when each 100oC block is added to cold water.

**Explain**

Were your prediction and explanation correct?

Try to improve your first explanation to explain what happens more clearly.

*Physics > Big idea PMA: Matter> Topic PMA3: Energy of moving particles > Key concept PMA3.2: Specific heat capacity*

|  |
| --- |
| **Response activity** |
| **Calorimeters** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Specific heat capacity is the amount of energy added to the thermal store of a material in order to increase the temperature of 1kg of that material by 1oC. |
| Observable learning outcome: | Describe what a material’s specific heat capacity indicates about the amount of energy transferred as it changes temperature. |
| Activity type: | Predict, explain; observe, explain (PEOE) |
| Key words: | Energy, temperature, mass, specific heat capacity, thermal store |

This activity can help develop students’ understanding by addressing the sticking-points revealed by the following diagnostic question:

* Diagnostic question: Metal and ice

|  |  |
| --- | --- |
| **P** | **PRIOR UNDERSTANDING**  This activity explores ideas that are usually taught at age 11-14, to aid transition from earlier stages of learning. |

**What does the research say?**

Most students correctly understand that raising the temperature of a particular object also increases the energy in its thermal store. However, fewer than half (n=342) of 11- to 15-year-olds in a study by Gonen and Kocakaya (2010) understood that, when they are at the same temperature, a larger mass of a material contains more energy in its thermal store than a smaller mass of the same material. It is common for students to think that an object at a higher temperature has more energy in its thermal store than an object at a lower temperature, even when the hotter object has a much smaller mass.

By age 13-14 Adadan and Yavuzkay (2018) found that about 50% of Turkish students (n=305) showed a clear scientific understanding of thermal concepts, increasing to 65% of those age 15-16 (n=213). However, they also found that 10-20% of 13- to 14-year-olds continued to regard heat as a material substance that could flow and that the numbers of those with this misunderstanding did not change much with age.

In addition to mass and temperature, the other factor that affects the amount of energy in the thermal store of a material is the specific heat capacity of the material. This is a measure of the amount of energy needed to raise one kilogramme of a material by one degree C. All sort of factors affect what the specific heat capacity of a particular material is. Never-the-less, specific heat capacity is a value that can be calculated from just a few measurements and then used to predict how a material will respond to heating or cooling.

Herrington (2011) suggests the traditional method of teaching specific heat capacity, which involves learning the related definitions and equations and using equations to determine the specific heat capacity in a laboratory setting contributes to confusion about specific heat capacity. Although students are often able to calculate values with the equation, they often do not often understand what specific heat capacity tells us about a material. Instead it can be more effective to introduce students to the concept of heat capacity and to guide them to make connections to their own personal experiences before introducing definitions and equations.

**Ways to use this activity**

Students should complete this activity in pairs or small groups, and the focus should be on the discussions. It is through the discussions that students can check their understanding and rehearse their explanations.

To begin, each group should discuss the activity and use their scientific understanding, firstly to predict *what* they think will happen, and then to explain *why* they think they are going to be right. If students in any group cannot agree, you may be able to direct them with some careful questioning.

Students now carry out the practical, or watch a demonstration. You will need to decide whether it is better for each group to carry out the practical and risk some unexpected observations, or to demonstrate the activity so that everyone *observes* the same thing.

* *The first student sheet for this activity is a set of instructions that students should follow to collect results.*
* *The second student sheet is for recording predictions, explanations and results.*

After the practical each group should be given the opportunity to change, or improve their explanation. A good way to review your students’ thinking might be through a structured class discussion. You could ask several groups for their *explanations* and put these on the whiteboard. Then ask other groups to suggest which explanation is the most accurate and the most clearly expressed, and through careful questioning work up a clear ‘class explanation’.

A useful follow up is for individual students to then write down explanations in their own words – without reference to the class explanation on the board (i.e. cover it up).

*Differentiation*

The quality of the discussions can be improved with a careful selection of groups; or by allocating specific roles to students in the each group. For example, you may choose to select a student with strong prior knowledge as a scribe, and forbid them from contributing any of their own answers. They may question the others and only write down what they have been told. This strategy encourages contributions from more members of each group.

**Equipment**

For each student/pair/group:

* Metal blocks (or equal mass)
* Calorimeter
* Thermometer (0-100oC)
* Stirring rod
* Measuring cylinder (100cm3)
* Tongs
* Beaker (250cm3)
* Bunsen burner, tripod, gauze, mat

**Technician notes**

Expanded polystyrene cups should be used as calorimeters, or ones made of some other insulating material.

The metal blocks need to have approximately the same mass for comparison and they need to fit easily inside the calorimeter. Suitable blocks can often be found in a set of density blocks.

This investigation can be carried out with just two types of metal, but it is better if several different metals can be compared. The metals should have specific heat capacities that vary as much as possible.

|  |  |
| --- | --- |
| Metal | Specific heat capacity / J/kg/oC |
| Lead | 160 |
| Brass | 380 |
| Steel | 420 |
| Iron | 460 |
| Aluminium | 900 |

The amount of water added to the calorimeter may need to be adjusted to an amount other than the 100cm3 stated on the student worksheet to ensure that the blocks used are fully submerged.

**Health and safety**

Students will be moving hot metal blocks with tongs above glass beakers.

Care and attention are needed for this. Tongs should be checked for suitability before heating the blocks, and the procedure could be rehearsed by students.

Thermometer bulbs are very delicate so stirring rods should be used to ensure the temperature of water in each calorimeter is uniform.

Practical work should be carried out in accordance with local health and safety requirements, guidance from manufacturers and suppliers, and guidance available from CLEAPSS.

**Expected answers**

The metal block with the largest specific heat capacity should increase the temperature of the cold water the most.

The increase in temperature of each block should be in proportion to their specific heat capacity. So if one block has twice the specific heat capacity of a second block, the amount it increases the temperature of the water should be two times as much.

Specific heat capacity is a measure of the energy that a metal block transfers to the water for each degree C that its temperature falls. The metal with the largest specific heat capacity transfers the most energy to the water and heats it to the highest temperature. If its specific heat capacity is three times greater, it has the capacity to transfer three times the amount of energy to the water.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG), from an idea by Herrington (2011).

Images: Peter Fairhurst (UYSEG).

**References**

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